KINEMATIC ANALYSIS OF A TELEVISED EVERSION ANKLE SPRAIN

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The purpose of this study was to perform a kinematic analysis of a non-contact eversion ankle sprain case study that occurred in the National Football League (NFL). Model-based image-matching analysis was performed to quantify ankle joint kinematics for the eversion sprain. Foot orientations are reported relative to the shank segment. At foot-ground contact, the ankle joint was dorsiflexed, externally rotated but neutral in the frontal plane. Peak eversion (50°) occurred 0.2 seconds later, with a maximum velocity of 426°/s, while peak dorsiflexion (64°) occurred with a greater maximum velocity (573°/s). Rotation in the transverse plane remained constant through ground contact. For this case, the combination of dorsiflexion at foot-ground contact and rapid eversion is associated with a non-contact eversion sprain.

KEY WORDS: sports medicine, injury mechanism, case study

INTRODUCTION: Identifying ankle sprain injury mechanisms may enhance our understanding of the development of chronic ankle instability (Gribble et al., 2016). Krosshaug and Bahr (2005) proposed a method to investigate such mechanisms - a model-based image matching (MBIM) technique that uses uncalibrated video footage to reconstruct the motion of a subject in three-dimensions using animation software. Until now, the body of evidence using MBIM to investigate injury mechanisms at the ankle has focused on sprains caused by an inversion motion (Fong et al., 2009, 2012; Mok et al., 2011a), stressing the lateral ligaments. The results from this combined analysis suggest that a combination of internal rotation with large inversion velocities (ranging from 509°/s to 1752°/s) over a short time period are central to inversion sprain mechanism. Analysis of accidental laboratory sprains obtained similar values and conclusions (Gehring, Wissler, Mornieux, & Gollhofer, 2013; Kristianslund, Bahr, & Krosshaug, 2011).
Eversion ankle sprain mechanisms should be considered due to their prevalence in sporting situations (Waterman et al., 2011), and the importance of eversion motion when traversing uneven terrain. In running studies, subtalar eversion velocities have been reported in a range from 115°/s (Dierks, Davis, & Hamill, 2010) to 207°/s (Snyder, Earl, O'Connor, & Ebersole, 2009). An injury threshold of 250°/s was identified for this study, where the aim is to use MBIM to identify potential injury mechanisms for a single ankle eversion case that occurred in an NFL athlete.

METHODS: Mok et al. (2011b) validated the MBIM method, using five cadaveric below-hip specimens to analyse ankle motion through bone-pin marker-based motion analysis system and MBIM. The validity measures reported are reassuring, reporting a root mean square error < 3°, inter-rater reliability levels ≥ 0.955 and intra-class correlations ≥ 0.948.
A single case study was selected for analysis – a non-contact eversion ankle sprain during a NFL 2013 pre-season game. The 23 year old quarterback landed awkwardly on his right leg during a rollout run in the third quarter. He continued to play on restricted timings for the first half of the season. Athlete height (1.91 m) and weight (100 kg) were obtained from his NFL athlete profile. The injury was defined as an eversion sprain if an unwanted motion caused excessive eversion during landing, the athlete had to withdraw for a brief period of time following the event, and post-match reports described the injury as an ankle sprain. Selection criteria for appropriate video footage included multiple views of the injury, clear and visible boundary lines, the injured limb not obscured for more than one frame and a resolution larger than 640 x 360 pixels. The selected footage had three views of the injury, with a frame rate of 30 Hz and a resolution of

1280 x 720 pixels. It was trimmed, deinterlaced and transformed into uncompressed AVI image sequences using Premiere Pro and synchronised in AfterEffects (both CC 2015, Adobe Systems Inc., San Jose, CA, USA).
Synchronisation was manually achieved by identifying key moments in the motion and comparing them with ‘normal speed’ footage. Broadcast frequency, used to determine the timescale for kinematics, was defined as the number of frames in 10 seconds displayed on the clock. The synchronised image sequences were rendered into one frame per second video sequences and imported into Poser 4 with Poser Pro Pack (Curious Labs Inc., Santa Cruz, CA, USA) for matching.

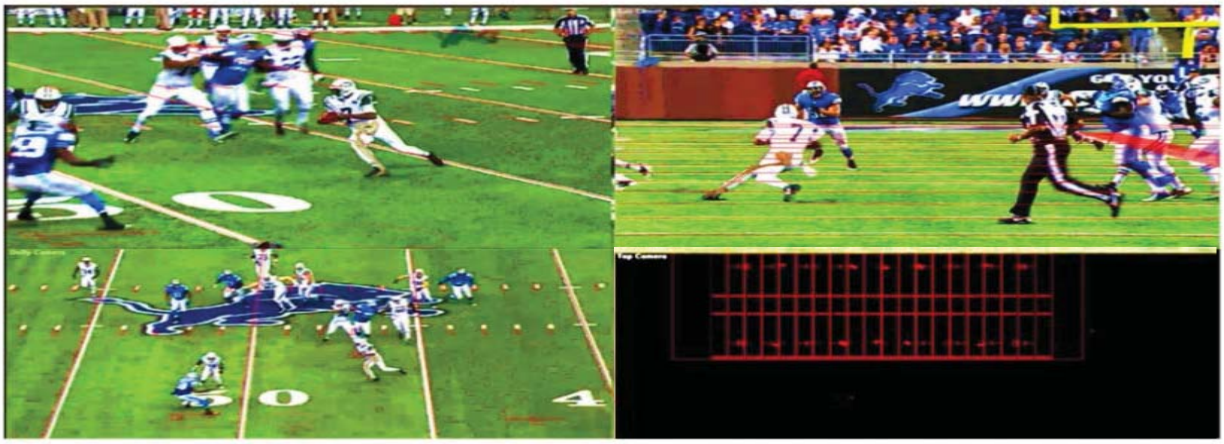

Figure 1. An example of the matching process, with three simultaneous views of the injury, and a birds-eye view in the bottom right corner.

A virtual environment of the American Football field was reconstructed in Poser where one meter was equal to 0.41 Poser units. The reconstructed field was manually aligned with the recorded field frame-by-frame by adjusting the camera orientation, position and focal length.
Body segment motion was replicated by matching a skeleton model (Zygote Media Group Inc., Provo, Utah, USA) to the recorded athlete. The skeleton model used for matching comprised of four segments (pelvis, thigh, shin and foot), with three degrees of freedom at the ankle joint and two degrees of freedom at both the knee and hip. A still image of the injured athlete was used to identify subject-specific body proportions, adjusting segment dimensions iteratively to identify the appropriate scaling parameters.
Working distally from the pelvis segment, the model was matched simultaneously to the three camera views of the athlete. When visual identification was not possible, tibial rotation was assumed to be fully distributed at the ankle - it is not considered a key factor in ankle injuries (Lynch, 2002). Individual parameters, such as foot segment orientation, were assessed in Poser to minimise the noise in calculated derivatives. An example matched sequence is shown in Figure 1. Angle time histories were imported into Matlab (MathWorks Inc., Natick, MA, USA), and joint angles were computed according to the joint coordinate system method (Grood & Suntay, 1983) using a custom-written script. Time zero of the injury was taken as foot touchdown, defined as the initial ground contact as observed from the multi-view video. Kinematics are presented according to the video frequency and reported in three dimensions. Ankle motion is reported with the foot segment relative to the shank segment orientation.

RESULTS: At the point of initial ground contact, the foot landed heel-first, causing the plantarflexion followed by dorsiflexion motion observed in Figure 2. At peak eversion (50°), there was minimal eversion velocity (78°/s) and high dorsiflexion velocity (569°/s), while internal rotation remained constant. Maximum eversion velocity of 426°/s was well above the threshold value of 250°/s, and occurred at foot-ground contact. Dorsiflexion velocity peaks around the time of peak eversion before dropping off suddenly, perhaps due to anatomical limitations.

DISCUSSION: Clinically, the proposed qualitative injury mechanism for eversion sprains is a combination of pronation, abduction and dorsiflexion (Ferber, Hreljac, & Kendall, 2009). The

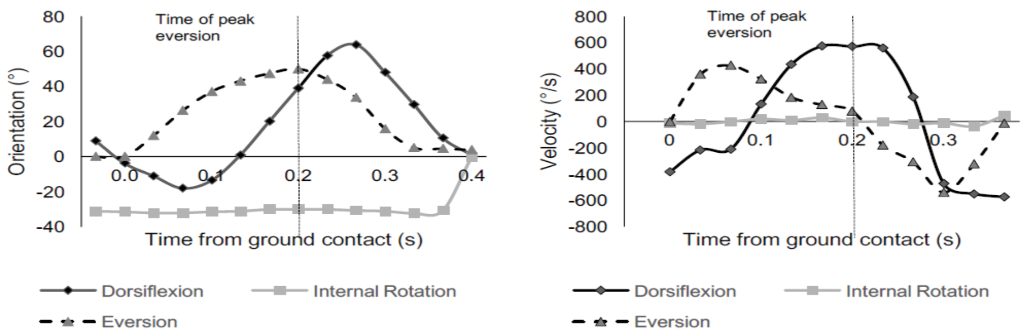

Figure 2. Ankle orientation (left) and velocity (right). Positive values represent dorsiflexion, eversion and internal rotation. Negative values represent plantarflexion, inversion and external

results from this case study support this clinical interpretation, with the foot touching down in a dorsiflexed position, plantarflexing slightly before dorsiflexing once again. This motion is common in heel-strike running, often seen in American Football due to distances run and the uneven playing surface. While the foot is not everted at touchdown, the initial contact position favours the joint to follow a pronated motion, evidenced by peak eversion velocity occurring 0.07s following foot-ground contact.

A healthy eversion range of motion (ROM) is considered to be approximately 20° (Boone & Azen, 1979), and maximum dorsiflexion observed in this case was 64°. The combination of dorsiflexion and eversion observed stresses the deltoid ligament, the posterior talofibular ligament, and, to a lesser extent, the anterior talofibular ligament (Colville, Marder, Boyle, & Zarins, 1990). In itself, the large ROM observed would be sufficient to injure these ligaments, provided the fibula doesn't restrict movement. It was discerned that both sagittal and frontal plane motions occur with high velocities, and this explosive torque may be a contributing factor to the injury mechanism.

The timing of peak dorsiflexion occurring 0.07 seconds and peak eversion 0.2 seconds following touchdown suggests that the medial ligaments are strained first, followed by the talofibular ligaments. Rapid changes in orientation have been shown to strain ligaments to the point of failure (Wei, Fong, Chan, & Haut, 2015). The eversion velocity of 426°/s, while higher than the threshold value, is not different from values reported by Chu et al. (2010) in running. A possible explanation is, qualitatively, the shank moved laterally while the foot segment remained planted, causing eversion motion to come from tibial displacement rather than a medial shift of pressure. This finding suggests the injury mechanisms substantially differ between inversion and eversion sprains. In 2012, Fong and coworkers concluded sagittal plane motion is not an essential component of inversion sprain injuries. However, the analysis from the present case study suggests that dorsiflexion does appear to have influence in eversion sprains. Sagittal plane motion appears to have a greater importance to eversion injury mechanism, and further research is required to strengthen these conclusions.

These results must be considered with caution, as the injury mechanisms suggested can only be speculated from observations and are limited by televised video footage frame rate. It cannot be said with certainty whether the abnormal eversion and dorsiflexion velocities and ROM observed in this case study are a cause or effect of the injury itself. Nonetheless, case reports are vital to the understanding of specific injury incidences. With increased data obtained from injuries occurring in a variety of sports, coaches, players and sports medicine personnel are better informed to prevent and treat the injury.

CONCLUSION: The present study used model-based image-matching analysis to analyse ankle joint kinematics in an eversion sprain case study. The results suggest a case-specific injury mechanism comprising of sudden eversion and dorsiflexion with constant internal rotation, agreeing with the clinical qualitative pathology. Maximum eversion occurred 0.2 seconds following initial ground contact, with a peak eversion velocity of 426°/s. The results from this MBIM analysis start the discussion for understanding the injury mechanism of medial ankle sprain injury.

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